Requesting Distant Robotic Action:
An Ontology of Work, Naming and Action Identification for Planning on the Mars Exploration Rover Mission

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Overview

- Method
- Mars Exploration Rover (MER) Mission background
- Understanding the Problem
- Answer to the Problem

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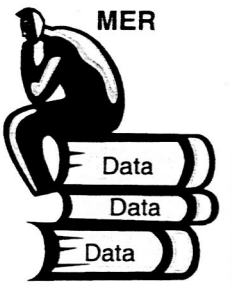
Ethnographic Methods for MER

- Data collection and analysis of:
  - field notes from in-situ observation and participation
  - video and photos
  - documents and artifacts
  - information created in software
  - system interactions between tools
  - information exchanged in meetings
  - nature of individual and group work
  - Interviews (formal and informal)
  - Email information and exchanges



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Assessing a Work System: Where to Begin?

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- Work System Analysis
  - What is the organizational structure? How do people access, display and share information?
  - What tools do people use?
  - What's in the software? What should be in the software?
  - How do people communicate?
  - What are the described processes (work process) vs. actual work (work practice)
  - What are the breakdowns and disconnects? What is the re-work?
  - When and where are decisions made? Who is responsible for what?
  - How do the facilities support the work?
    - Rooms, work stations, tables, chairs, printers, projection screens
  - What is missing?
    - Minimal support of standard information sharing formats: ex: Copiers and Printers not easily accessible, etc.

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"Mission" Ethnography at NASA

Rules of Mission ethnography:

1. If you have a badge and are taking up room in meetings or tests, you must contribute and add value.
2. Launch, landing and surface operations will meet the mission timeline whether you contribute or not.
3. Feedback that is late is useless; input on software development, systems integration and training must meet the above timelines.
4. Mission personnel will remember if you contributed or not and this will influence their future interactions with you. (See 1 above)
5. Processes and Procedures will be re-worked into the mission. They are the only thing that does not have a freeze and change control limitations.

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Mars Exploration Rover Mission (MER)

- **Science Mission**
  - **Launched: June/July 2003**
  - **Landed: January 2004**
  - **Run for NASA by Jet Propulsion Lab (JPL) in Pasadena, CA. Ames contributed to the mission.**
  - **Mission run on Mars time (Martian sol = 24:39 in Earth time)**
    - **Solar powered rovers**
    - **Sunlight and daytime temperatures for cameras and other instruments**
    - **Objective: search for evidence of past water**
- **Work Cycle**
  - **Activity Planning for rover work and batch of commands sent every sol for rover execution on the next sol**
  - **Nominal mission lifetime 90 sols per rover, spanning four months January thru April**

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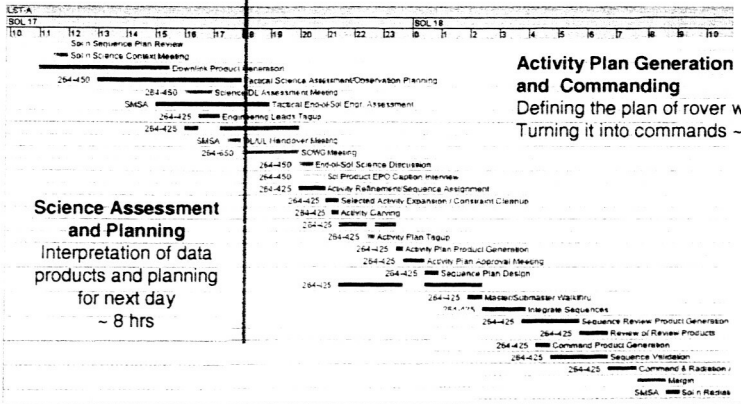
Daily/ "Soly" Timeline for Work, Planning and Commanding

- Day/Sol split into two phases:

Downlink: Receive data from the rover, do health validation and data product generation. Decide on and generate science plan requests

Uplink: Prioritize, constrain, plan rover activity. Generate, validate, and transmit commands to the rover



Activity Plan Generation and Commanding
Defining the plan of rover work and Turning it into commands ~ 14 hrs

Science Assessment and Planning
Interpretation of data products and planning for next day
~ 8 hrs

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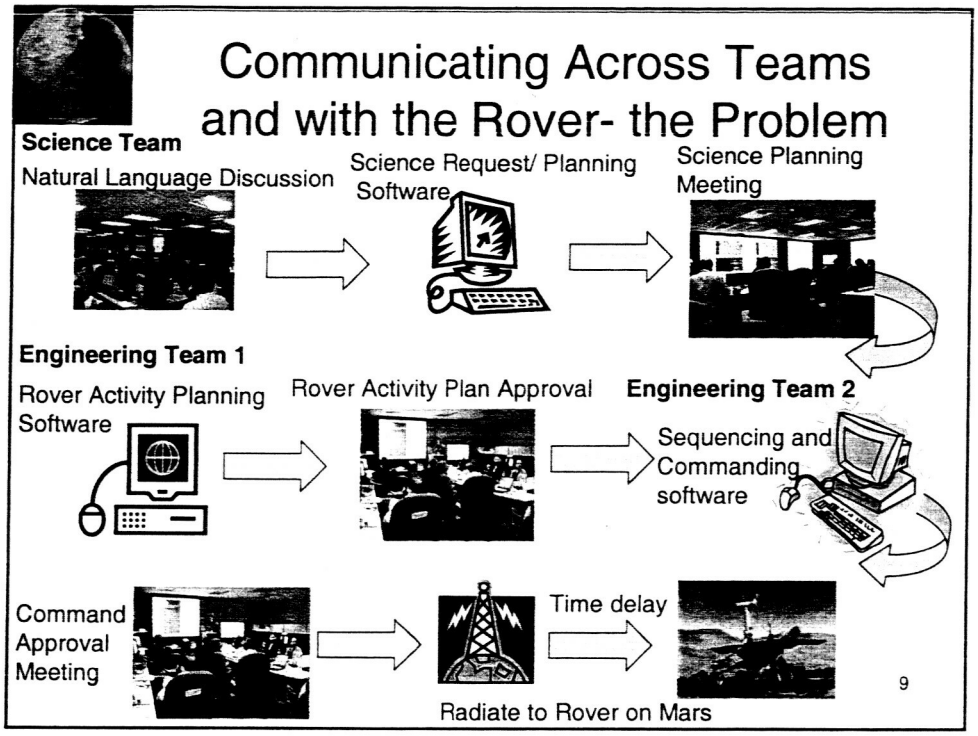

Communicating Across Teams and with the Rover-The Problem

- Problem: how do you convey information across teams and to a rover when participants:
  - speak different technical languages
  - focus on different issues
  - have different tasks
  - use different software tools
  - must communicate from humans to a robot
- Not just an academic exercise, the answer influenced mission software design

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Where Did We Start?

- Field observations in April 2001 Field Test identified problems with "naming" and target identification
- Minimal software support
  - Identify "target" only.
  - Target identification did not "push" to other work stations
- "Working" naming convention decided on by science team
- Working procedures called for
  - each "theme group" to use one name for a target for discussion
  - the whole group renamed chosen targets when science requests and target decisions were finalized

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Naming Convention April 2001 Field Test

Small group discussion name		Name in software
Target sol4geo5	→	Target "Aaron"

Repeat work on same area got a new name		Name in software
Target sol6geomin3	→	Target "Martin"

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Naming Convention FIDO 2001

- Name change:
  - required Scientists to maintain separate notes outside of the science software tool to keep track of name changes
  - made it difficult to track what activities had been done over time
  - created confusion during and after name changes

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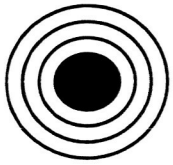
Post FIDO 2001 Analysis

Target "Aaron"



Name change:
1. causes confusion
2. makes it difficult to track changes
3. makes it difficult to keep track of related work

What else is wrong with this picture?

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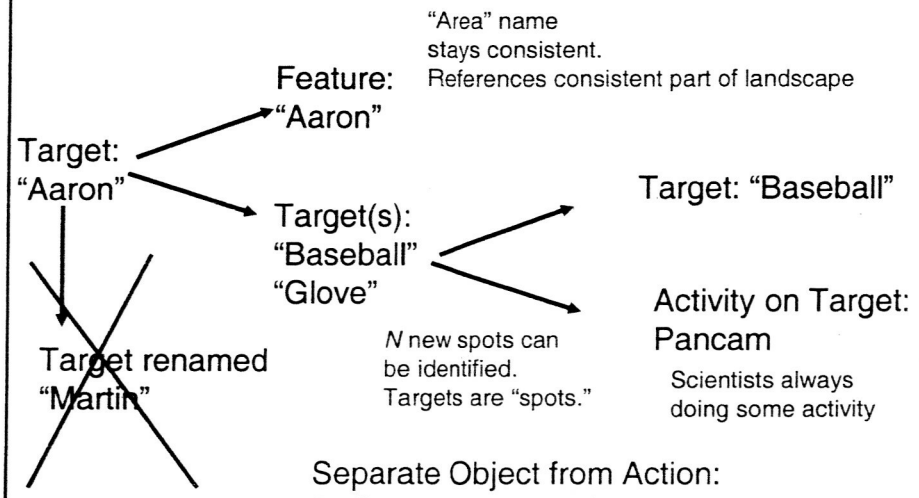
Post FIDO 2001 Analysis: Deconstructing the Problem



Separate Object from Action:
Define an ontology for robotic action

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Deconstructing the Name for Scientific Work

- Deconstruct the components of the work
  - Features, Targets, Activities
  - Separate Objects from Actions
- Reconstruct with an appropriate organizational grouping
  - Features contain Targets
  - Observations group activities for related scientific work
- Determine an ontology of types of things to be named, supported and passed from one team to another

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Communicating Across Teams and with the Rover- An Answer

- Implement a "naming" convention that:
  - describes the work and the environment for the work
  - allows for natural language discussion
  - is consistent
  - identifies components that are relevant to all teams
    instrument such as Pancam or RAT
  - identifies both the activity and the object on which the work will be done Instrument and Feature
  - identifies formalized concepts activity or method
  - carries across software tools
  - can be translated into work for the rover
- Ex name: Pancam_surveyaround_Adirondack

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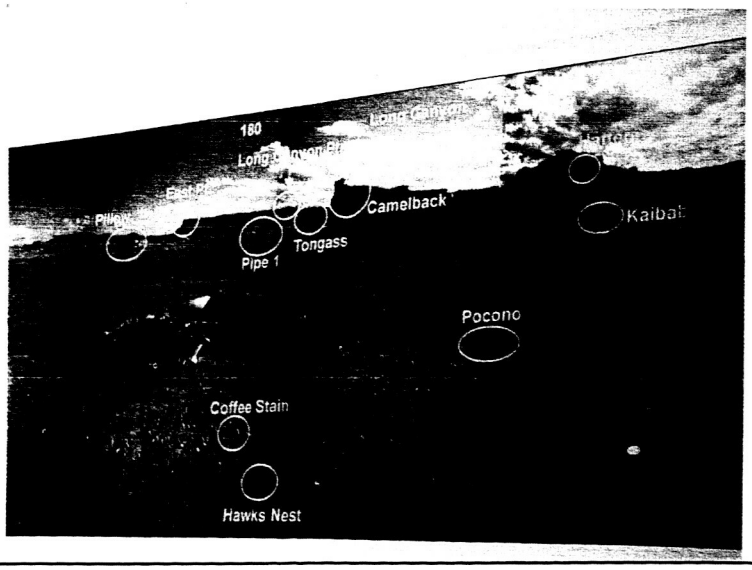
Feature Map from May 2002 Field Test



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Examples of Instrument Names, Methods and Other Identifiers/Constraints for use in the Naming Template

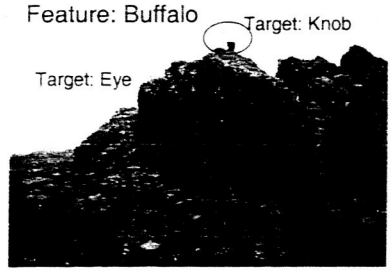
Instrument	Method and/or	Other Identifiers/Constraints
APXS •Haz •MB •MI •MiniTES •Nav •Pancam •RAT •Rover •IDD (shorthand for two or more in-situ instruments in one obs) •PMA (shorthand for two or more remote sensing instruments in one obs) **Note**: PMA and IDD activities belong in separate observations.	• Accordion • Approach • Blind (for MiniTES activity without a supporting image or Pancam activity without a target) • Comparison • Drive • Drive camera use methods "quick look", "rubber neck", "systematic" • Movie • Rat • Scratch • Sniff • Surveys: Survey around, between, covering, from . . to, including • Sweep • Tau • Trench	• Afternoon • Around • Between • Contiguous (identify whether Mast Relative or Time relative in notes field • Elevation • Location/reference to a region or area • Long • Morning • Morning after • N, S, E, W (directions) • Pre • Post • Short • Soil

MER Mission
1-03-04

"Cheat Sheet" for MER Object Naming

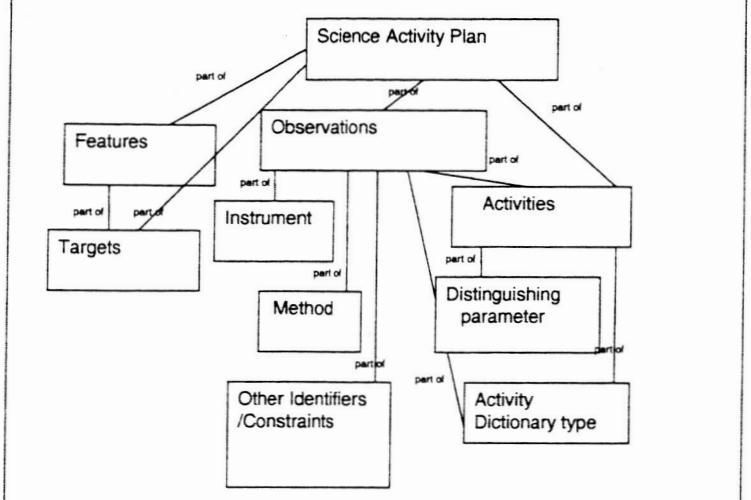
- Standard Template for naming Observations is:
  - Instrument_Method and/or OtherIdentifiers_Feature
- Instrument short hands
  IDD = use of two or more in-situ instruments in one observation
  PMA = use of two or more remote sensing instruments in one observation
- Standard Template for naming Activities so they are *unique* and can be distinguished from activity types:
  - Distinguishing parameter(s)_Target

Example 1:
Observation name: PMA preApproach Buffalo
--- Activity name: red 2x2 Knob
(Pancam is activity type)
--- Activity name: 5x5oversamp Knob
(MiniTES is the activity type)
Example 2:
Observation name: Mini-TES preApproach BuffaloSoil
Activity name: singleSpot AZ30EL0 (Mini-TES is the activity type)



Notes: Do not leave spaces between word in method or other identifier fields
Underscores will be added by downstream s/w where ever there is a space between words.

An Ontology for Science Activity Planning



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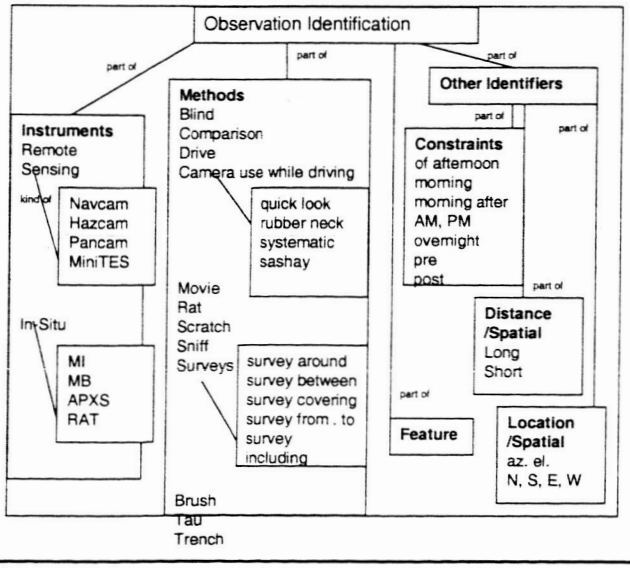
An Ontology for Observation Identification



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Example Names from End of Nominal Mission

- MTES Elevation Sky AND Ground ODY PM
- Pancam Midway 1 4Fs (Four Filters on Soil)
- PM ODY mini TES Elevation Sky AND Ground Beta Pancam Photometry Photometric Equator[1]
-

[1] This is a multispectral Pancam along the photometric equator. The Beta Pancam Photometry was an addition to the name to group four coordinated observations together.

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Key Insights

- Observation of work practice allowed us to:
  - understand the work the being done
  - deconstruct the component parts
  - reconstruct and devise an organizational structure to support information management and exchange from natural language to rover
  - determine the important information to transition to other teams and through software and tools
  - maintain flexibility in a constantly "changing" mission and Martian landscape

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